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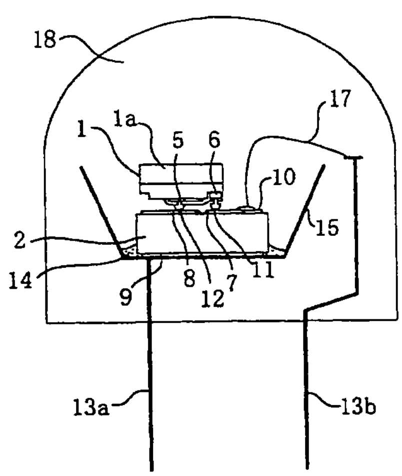
(54) LIGHT EMITTING ELEMENT, SEMICONDUCTOR LIGHT EMITTING DEVICE, AND METHOD FOR MANUFACTURING THEM

(57) A GaN-based LED element **1** having a double heterostructure, which includes a GaN layer and the like and is formed on a sapphire substrate, is mounted face-down on a Si diode element **2** formed in a silicon substrate. Electrical connections are provided via Au microbumps **11** and **12** between a p-side electrode **5** of the GaN-based LED element **1** and an n-side electrode **8** of the Si diode element **2** and between an n-side electrode **6** of the GaN-based LED element **1** and a p-side electrode **7** of the Si diode element **2**. The Si diode element **2** functions to protect the LED element **1** from an electrostatic destruction. The Si diode element **2** has a backside electrode **9** connected to a leadframe **13a**. The p-side electrode **7** of the Si diode element **2** has a bonding pad portion **10** connected to a leadframe **13b** via an Au wire **17**.

Fig. 20



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Description

TECHNICAL FIELD

[0001] The present invention relates to a light-emitting element comprising a semiconductor multilayer film formed on an insulating substrate, to a semiconductor light-emitting device including such a semiconductor light-emitting element, and to manufacturing methods therefor. In particular, the present invention is properly applicable to a light-emitting element (LED) using a gallium-nitride-based compound semiconductor formed on a sapphire substrate and to a light-emitting device comprising such a light-emitting element.

BACKGROUND ART

[0002] As the demand for optical devices, such as liquid-crystal display devices, has grown in recent years, various light-emitting elements have found practical applications. Among them is a gallium-nitride-based compound semiconductor ($In_XAl_YGa_{1-X-Y}N$, $0 \leq X$, $0 \leq Y$, $X+Y \leq 1$), which is not only on the current market as a high-intensity blue and green light-emitting diode (LED) but also receiving attention as a prospective material for composing a blue laser diode, a UV sensor, and a solar cell in the future.

[0003] Figure **4A** is a plan view of a conventional GaN LED element which is commercially available. Figure **4B** is a cross-sectional view taken along the line **B-B** thereof. Figure **4C** is a cross-sectional view taken along the line **C-C** thereof. It is to be noted that the thickness of each semiconductor layer shown in the drawings does not necessarily coincide with the actual thickness thereof. Figure **5** is a cross-sectional view of a conventional LED lamp which is commercially available. The GaN LED element **40** has a double heterostructure including a GaN buffer layer **31**, an n-type GaN layer **32**, an InGaN active layer **33**, a p-type AlGaN layer **34**, and a p-type GaN layer **35** which are stacked sequentially in layers on the top face of a sapphire substrate **30**. The top face of the n-type GaN layer **32** has a stepped configuration consisting of an upper-level portion and a lower-level portion. An n-side electrode **36** made of Ti and Au is formed on the top face of the lower-level portion of the n-type GaN layer **32**. The aforesaid InGaN active layers **33**, the p-type AlGaN layer **34**, and the p-type GaN layer **35** are stacked sequentially in layers on the top face of the upper-level portion of the n-type GaN layer **32**. A transparent electrode **37** for current diffusion made of Ni and Au is formed on the top face of the p-type GaN layer **35**, followed by a p-side electrode **38** formed thereon. Since the GaN LED element **40** is formed by using the insulating sapphire substrate, each of the two electrodes is formed on the top face of the sapphire substrate. The top face of the GaN LED element **40** serves as a light-emitting face, which is coated with a protective film **39** except for the bonding pad portions **36a** and **38a** of the n-side and p-side electrodes **36** and **38**. The GaN LED element **40** is die-bonded to a die pad on the tip of a leadframe **44a** via an insulating adhesive **43**. The n-side electrode **36** of the GaN LED element **40** is connected to the leadframe **44a** via an Au wire **41**, while the p-side electrode **38** thereof is connected to a leadframe **44b** via an Au wire **42**. The respective tip portions of the leadframes **44a** and **44b** carrying the GaN LED element **40** are molded with a transparent epoxy resin **45** to constitute the LED lamp.

[0004] The foregoing conventional light-emitting element has the following problems.

[0005] To achieve wire bonding for providing an electrical connection between the GaN LED element **40** and another element or the like as described above, each of the bonding pad portions **36a** and **38a** should be configured as a circle having a diameter of 100 μm or more or a square having sides of 100 μm or more. Moreover, since the two electrodes **36** and **38** are formed on the light-emitting side, the light-emitting efficiency is degraded. If the bonding pad portions **36a** and **38a** are provided with a sufficiently large area and the light-emitting face is provided with a sufficiently large area for emitting a sufficient amount of light, the size reduction of the light-emitting element will be limited and the scaling down of the light-emitting element will be difficult.

[0006] It is therefore a primary object of the present invention to provide a semiconductor light-emitting element and a manufacturing method therefor, which enable a reduction in the area required by the electrodes to achieve electrical connection of the light-emitting element, the scaling down of the entire light-emitting element, and improvements in the brightness and light-emitting efficiency of the light-emitting element.

[0007] Another object of the present invention is to provide a light-emitting device comprising the aforesaid light-emitting element and a manufacturing method therefor.

DISCLOSURE OF INVENTION

[0008] A light-emitting element according to the present invention comprises: a substrate; a first-conductivity-type semiconductor region formed in the semiconductor substrate; a second-conductivity-type semiconductor region formed on a portion of the first-conductivity-type semiconductor region; a first electrode formed on a portion of the first-conductivity-type semiconductor region other than the portion in which the second-conductivity-type semiconductor region is formed; and a second electrode formed on the second-conductivity-type semiconductor region, the light-emitting element further comprising a plurality of microbumps made of a conductive material and formed on the first and second electrodes, wherein the number of the microbumps formed on the first electrode is one and the number of the microbumps formed on the second electrode is one or more.

present invention is not limited thereto. For example, it is also possible to mount the GaN LED element on an active element, a passive element, or a base substrate by flip-chip connection or alternatively mount other active and passive elements on the GaN LED element by flip-chip connection.

[0096] The light-emitting element according to the present invention is not limited to the GaN LED element but may be another light-emitting element. However, since the GaN LED element is formed on a transparent and insulating sapphire substrate and the p-side electrode and the n-side electrode are formed on one side thereof, it can exert remarkable effects if the present invention is applied thereto.

[0097] The substrate of the light-emitting element according to the present invention is not necessarily transparent because, if the substrate is opaque, it is sufficient to obtain light from the opposite side of the substrate. However, the substrate made of a transparent material improves light-emitting efficiency, as described above, since it allows light to be obtained from the side opposite to the p-side and n-side electrodes.

[0098] In the process step of a probe test for testing the characteristics of the GaN LED element and in the assembly process step for dividing the wafer into individual chips and mounting them on leadframes or the like, there are possibilities that the following problems occur, which can be subdivided into three types.

[0099] The first type of problems occur in the assembly process. In the case of dividing the wafer, in which GaN LED elements are formed, into individual chips (in each of which one GaN LED element is formed) and mounting each of the chips on leadframes or the like, the arms of a die bonder or the like recognize the chip placed with the microbumps facing downward and come to pick it up. In that case, however, the chip supported by the two microbumps is likely to tilt, which may lead to trouble associated with the chip recognition and pick-up operation performed by the arms. On the other hand, if the chip is bonded to leadframes or the like via the microbumps in accordance with a method in which the Au microbumps are welded and bonded with the application of load, heat, and ultrasonic waves, the microbumps of reduced heights may result in an undesired contact between the chip and the leadframes at a portion in which the microbumps are not formed. Such an undesired contact causes the problems of a short-circuit failure and the peeling off of the electrode due to the ultrasonic wave.

[0100] The second type of problems occur in the process step of a probe test. As stated above, the light-emitting area can be maximized when the n-side electrode 6 of the GaN LED element is in minimum size. For this purpose, the electrode is preferably sized to allow one columnar or mushroom-shaped microbump with a diameter on the order of 30 μm to be formed thereon. In this case, the n-side electrode 6 is preferably configured as a circle having a diameter on the order of 60 μm. However, the microbump may be destroyed by a probe needle in contact therewith in the process step of a probe test for testing the characteristics of the element.

[0101] The third type of problems also occur in the process step of a probe test. In the case of performing a probe test by means of a normal prober, a wafer, in which GaN LED elements are formed, are placed on a stage with the electrodes facing upward and fixed with a vacuum chuck. The characteristics of the element are tested by bringing the probe needle into contact with the electrodes from above the wafer. However, since light is obtained from the back face of the sapphire substrate of the GaN LED element and a detector for measuring the intensity and wavelength of light is disposed above the stage, the amount of light reaching the detector positioned above the stage may be insufficient.

[0102] The following embodiment relates to a light-emitting element with a flip-chip structure, in which microbumps are formed and which allows the test process and the assembly process to be performed without trouble.

Embodiment 2

[0103] Figure **6A** is a plan view of a GaN LED element **1** according to the present embodiment and Figure **6B** is a cross-sectional view taken along the line **D-D** thereof. The present embodiment is characterized in that one dotted microbump is formed on the n-side electrode **6** of the GaN LED element **1** and that two dotted microbumps are formed on the p-side electrode **5** thereof.

[0104] Referring to Figures **6A** and **6B**, a detailed description will be given to the structure. As shown in the drawings, the GaN LED element **1** has a double heterostructure including a GaN buffer layer **31**, an n-type GaN layer **32**, an InGaN active layer **33**, a p-type AlGaN layer **34**, and a p-type GaN layer **35**, which are stacked sequentially in layers on the top face of a sapphire substrate **30**. The top face of the n-type GaN layer **32** has a stepped configuration consisting of a upper-level portion occupying the major part of the top face and a lower-level portion occupying the remaining minor part thereof. An n-side electrode **6** made of a Ti/Au multilayer film and a Mg/Au multilayer laminated thereon is formed on the top face of the lower-level portion of the n-type GaN layer **32**. The aforesaid InGaN layer **33**, p-type AlGaN layer **34**, and p-type GaN layer **35** are stacked sequentially in layers on the top face of the upper-level portion of the n-type GaN layer **32**. A p-side electrode **5** made of Mg and Au is provided directly on the top face of the p-type GaN layer **35** with no intervention of a transparent electrode. One dotted microbump **24** made of Au or an Au alloy is formed on the top face of the n-side electrode **6**, while two dotted microbumps **25** made of Au or an Au alloy are formed on the top face of the p-side electrode **5**. The entire surface of the element is covered with a protective film **39** except for the micro-

Fig. 6A

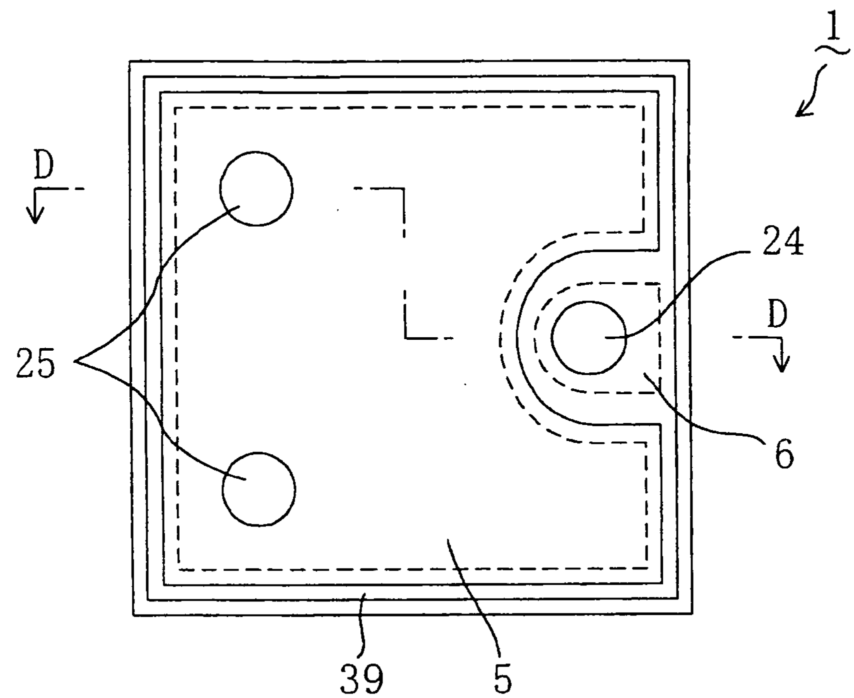

Fig. 6B